Workshop: Engineering Reasoning - An Approach to Increasing the Appeal of Introductory Engineering Courses to All Students

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Purpose: In this workshop participants will learn to incorporate the theme of engineering reasoning into Introduction to Engineering courses. Engineering reasoning is the set of practices engineers use to create technological systems. Incorporating this framework makes it possible to appeal to the needs of both students already anticipating a major in engineering and those that have a more tentative interest in the subject. The workshop will outline the approach, describe some results that have been obtained, and conduct a hands-on session to help participants adapt this framework to some of their current Introduction to Engineering course materials.

Need: Thus far engineering lacks a true gateway course that can attract undergraduates with a tentative or casual interest in the subject, introduce these students to a meaningful body of knowledge characteristic of the discipline, and provide a foundation for further study for those that might choose to pursue the subject in more depth or as a career. Engineering is in need of an introductory course similar to disciplines such as economics, psychology, political science, philosophy, or even the geosciences. Economics, psychology, political science are among the most popular undergraduate majors yet few students are exposed to these disciplines in high school. In many cases, an appealing gateway course draws students into these subjects.

Introduction to Engineering courses typically assume that students electing to take the course already have a high level of commitment to a career in engineering. Exposure to the engineering design process is a common course element along with development of skills related to engineering practice such as programming, use of spreadsheets, teamwork, ethics, and communication. Generally such Introduction to Engineering courses do not have significant constituencies of undecided students exploring engineering as a career option. This is regrettable because it has been shown that non-engineers have a high interest in understanding how things work and in having a more empowered relationship with technology [1]. Lack of an appealing gateway course could be partly responsible for the lack of gender and ethnic diversity in engineering.

Method: To develop an Introduction to Engineering course that can meet the needs of undergraduates with varying degrees of commitment to engineering an approach was developed that focuses on the nature of technological systems and the various processes utilized by

engineers in creating new technology [2-3]. This framework summarizes all the activities involved in engineering reasoning:
1.) Technology: Form, Function, and Value
Technology is created to solve problems and satisfy needs. The function is the problem to be solved or a need to be satisfied. Function, what a particular object can do, is determined by the form or the physical properties and characteristics of that object. The form of any object can provide a variety of different functions.

2.) Systems transforming materials, energy, and information.
Technological products are systems that transform inputs into outputs. Inputs and outputs take the form of flows of materials, energy, and information.

3.) Function provided by components combined into systems.
Overall system function is provided by components which combine to form systems. The term subassembly is sometimes used to describe intermediate stages of component groups. Some components are utilized for the purposes of controlling system behavior.

4.) Components, phenomena, science, mathematical models, prediction.
Components accomplish transformations through utilization of physical phenomena. Transformations and component behavior are frequently expressed in mathematical form. Predictive capabilities of mathematics facilitate component interconnection and achievement of system performance requirements.

5.) Diverse phenomenon; interaction through flows
Most technological systems utilize a diverse range of phenomena. Components utilizing different phenomena must interact through exchanging the same type of material, energy, or information flow.

6.) Component functions transfer across systems; component families
Components can be used to provide the same subfunction in systems with different overall function. Component variations offer diverse features around the same core function and principle.

7.) Systems become components, systems are sociotechnical.
There is no absolute distinction between a component and a technological system. One technological system can become a component in another system. Technological system boundaries are arbitrary and depend upon the intent of a particular analysis. Technological systems are sociotechnical in nature encompassing social and cultural interactions.

8.) Technological system domains.
Engineering design domains exist around collections of related components and core principles.

9.) Technological system design, component ensembles, representations
Systems result in utility exceeding that of individual components. Technological system design envisions function structures to achieve overall system function. Components solve subproblems or subfunctions within the system. Component parameters are adjusted in accordance with

desired features, system performance, and requirements of the intracomponent interactions. The design process employs form and function representations of the system. System designs require compromise between competing objectives.

10.) Evolution of technological systems.
Technological systems frequently evolve through substitution at the component level. Specific modes include merging of separate components into integral structures, optimization of component features, proliferation of added subfunctions, and substitution of component operating principles.

Implementation: We have found that implementation of the engineering reasoning approach is successful when course topics and design activities focus on technological domains. Each domain consists of a representative system, major components, operating principles, and applications. In the hands-on section of the workshop, how faculty can adapt this approach to their existing activities will be facilitated. Several specific examples will be made available.

Results: Both engineers and non-engineers show increases in learning outcomes and confidence as illustrated in Figures 1 and 2. Females attain par with male students in design self-confidence.

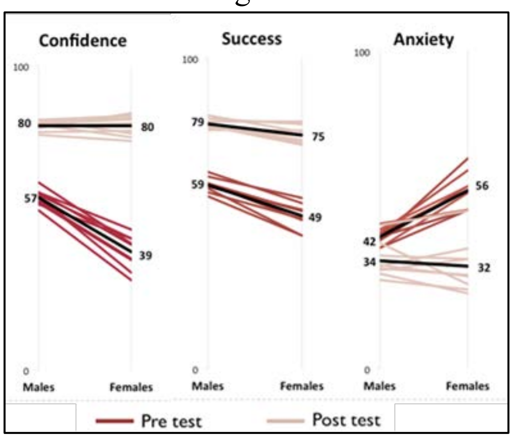

Figure 1: Increases in Engineering Students' Confidence and Success, and Decrease in Anxiety using [4].

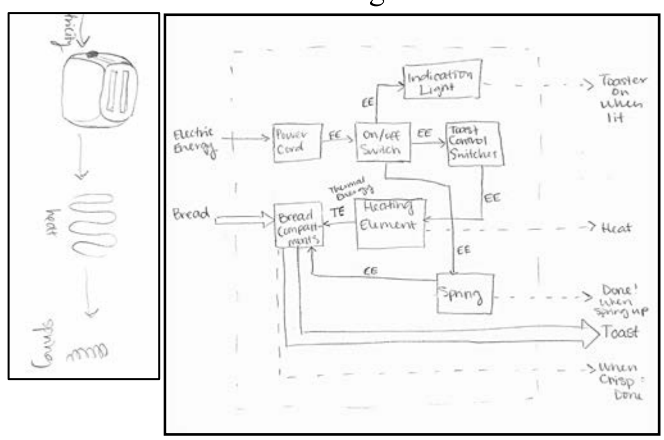

Figure 2: Changes in a non-engineers' explanation of how a toaster works. Pre and post test results.

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References:

1. Sarfaraz, A.R., and T.A. Shraibati, (2004, June), *Responding to Expectations of Non-Technical Students*. Paper presented at 2004 ASEE Annual Conference & Exposition, Salt Lake City, Utah., https://peer.asee.org/12959
2. Krupczak, J., & Mina, M., & Disney, K. A. (2017, June), *A Framework for an Engineering Reasoning Test and Preliminary Results.* Paper presented at 2017 ASEE Annual Conference & Exposition, Columbus, Ohio. https://peer.asee.org/27463
3. Krupczak, J., & Mina, M. (2015, June), *Work in Progress: An Approach to Engineering Literacy Emphasizing Components, Functions, and Systems* Paper presented at 2015 ASEE Annual Conference & Exposition, Seattle, Washington. https://peer.asee.org/25084
4. Carberry, A.R, Hee Sun Lee, Matthew W. Ohland, Measuring engineering design self-efficacy, *Journal of Engineering Education*, V99n1, January 2010.